

1 **Am stressed, must travel: The relationship between mode choice and commuting stress**
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ABSTRACT

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3 The stress of commuting has serious public health and social implications. By comparing stress
4 across different modes it is possible to determine which modes are more heavily contributing to
5 this potential health and social issue. This study uses a large-scale university travel survey to
6 compare commuter stress across three modes of transportation (walking, driving, and using
7 public transit). It also investigates the specific factors that contribute to stress using these modes.
8 Using ordered logistic regressions, the study develops a general model of stress and three mode-
9 specific models. Results show that driving is the most stressful mode of transportation when
10 compared to others. We also find that stressors for some modes are not stressors for others.
11 Knowing which specific factors make certain modes stressful will help transportation and public
12 health professionals make commuting a safer, more enjoyable, and less stressful activity; in turn
13 this could mitigate the potentially serious health outcomes of a stressful commute.

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INTRODUCTION

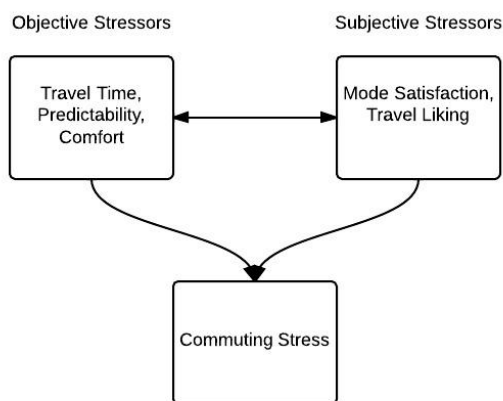
1 Many recent studies in transportation have focused on the personal experience of
2 commuters. A person's satisfaction with their trip, overall life satisfaction, and stress
3 experienced while commuting have become increasingly crucial parts of our understanding of
4 travel behavior, especially regarding mode-choice. Mode-switching may be inhibited because
5 certain physical and mental health implications are associated with a mode (Abou-Zeid, Witter,
6 Bierlaire, Kaufmann, & Ben-Akiva, 2012). Findings from studies that focus on the personal
7 experiences of commuters can have real policy implications by suggesting that factors that may
8 inhibit the uptake of more sustainable modes of transportation should be minimized, while
9 factors that make these modes more attractive to users should be explored.

10 Stress is one of the most serious physical and mental health implications of commuting.
11 Almost all commuting can be stressful—rushing to get to work or school in the morning is often
12 an unpleasant experience—and some modes may be causing more stress than others.
13 Discovering the mode-specific factors that contribute to a stressful commute highlights where
14 policy focused on increasing sustainable mode-share can be effective. Sustainable mode use can
15 be made more attractive by minimizing the factors that make sustainable modes stressful.
16 Perhaps more importantly, commuting is almost ubiquitous: a hefty share of any population
17 travels daily and, correspondingly, the stress experienced while commuting affects a large
18 number of people.

19 Factors contributing to stress during a commute can be broadly grouped into two
20 categories (Novaco, Stokols, & Milanesi, 1990). First, there are objective or environmental
21 stressors. These stressors negatively impact a person's control or comfort while commuting.
22 Second, there is the subjective experience of these stressors, which are influenced by (for
23 example) the satisfaction a person has with a mode. These personal subjective factors act as a

1 filter through which objective stressors are experienced. This interaction between personal
2 experience and objective stressors is derived from the work of Raymond Novaco (1990) and
3 Meni Koslowsky (1997) , and is shown in Figure 1.

4



5

6 **FIGURE 1 Study Framework**

7

8 In order to better understand the factors leading to a stressful commute, this study uses a
9 large-scale university travel survey to compare commuter stress across three modes of
10 transportation (walking, driving, and using public transit) during a cold snowy day. By
11 highlighting which factors lead to stress on different modes, transportation planners, engineers
12 and policy makers can better understand the factors that can make the commute more enjoyable
13 and provide a less stressful experience.

14

15 **LITERATURE REVIEW**

16 What is stress? Lazarus and Launier (1978) define stress as a situation where the
17 environment overwhelms the person: “these relationships refer neither to person nor environment
18 as separate variables, but they describe a balance of forces such that environmental demands tax
19 or exceed the resources of the person.” Other seminal work on stress echo this definition (see, for

1 instance, Fink, 2000; Selye, 1976). Furthermore, commuting has been linked to stress numerous
2 times (for a review see, Novaco & Gonzales, 2009). The experience of being stuck in traffic or
3 waiting for a delayed train is understandably a hardship and quite common. These and other
4 demands experienced while commuting often lead to stress. Yet, the relationship between
5 commuting and stress is not clear. For example, just because a delay is experienced does not
6 mean that the user experiencing that delay is necessarily stressed.

7

8 **The Effects of Stress**

9 Commuting stress (especially if it is unduly associated with specific modes) may inhibit
10 people switching to a more sustainable mode of transportation. Certainly, this is a concern. Also
11 of concern are the potential public health effects of stress, and, consequently, the serious health
12 and life satisfaction implications of stressful commuting. Longer commutes by car, for instance,
13 have been related to an increased risk of heart attack and obesity (Hoehner, Barlow, Allen, &
14 Shootman, 2012). In particular, the stress of commuting has been linked to poor quality sleep,
15 exhaustion, depression, and feelings of poor health (Gee & Takeuchi, 2004; Hansson, Mattisson,
16 Björk, Östergren, & Jakobsson, 2011). Commuting stress has also been shown to negatively
17 impact a person's ability to focus or complete tasks (Wener, Evans, & Boatley, 2005). Poor job
18 performance and shortened job tenure, no doubt exacerbated by these health and mental effects,
19 are also linked to commuting stress (Koslowsky, Kluger, & Reich, 1995; Novaco, et al., 1990).

20 Nevertheless, the view that commuting, and travel in general, is an unavoidable burden
21 has come under much criticism. Mohktarian and Salomon (2001) have argued that travel is not
22 always a derived demand. Rather, travel, including commuting, can be enjoyed for its own sake.
23 A recent study showed that travel is linked to higher life satisfaction (Ory, et al., 2004). Morris

1 and Guerra (2014) have argued that those who are happy are more likely to travel. A recent
2 Swedish study demonstrated that feelings while commuting are generally positive or neutral
3 (Olsson, Garling, Ettema, Friman, & Fujii, 2013). Enjoying one's commute may be linked to
4 notions of a desired minimum distance between a person's home and work locations.
5 Commuting time may be enjoyed as a time to decompress or unwind, and as a necessary
6 transition between home and work. Interestingly, this may have an effect on stress as well. Those
7 who have no commute report being more stressed than those who commute less than thirty
8 minutes (Haider, Kerr, & Badami, 2013). In this way, commuting, as an activity that both
9 positively and negatively affects the commuter, is a significant player in a person's overall
10 subjective well-being (Reardon & Abdallah, 2013).

11

12 **The Causes of Stress**

13 There are two major objective variables that help explain the forces that cause stress:
14 measurements of control and comfort. These two variables come out of the wealth of literature
15 focusing on the impedance model of commuting stress, first developed by Novaco et al. (1979).
16 Travel impedance is the notion that specific stressors (traffic congestion, for instance) *impede*
17 one's commute. At its most basic form, the degree of impedance is defined by the distance
18 traveled and the time it took to travel that distance; high impedance occurs when one is traveling
19 slowly (Novaco, et al., 1979). Recent studies have also investigated how lengthy travel distances
20 relate to commuting stress (Ettema, Garling, Olsson, & Friman, 2010; Stutzer & Frey, 2008)
21 However, the stress of this impedance is mediated by a variety of factors. Control is seen as a
22 mediator of commuting stress. The level of impedance during the trip may be a cause of stress,

1 but having personal control of one's own trip lessens this stress (Novaco, et al., 1990; Schaeffer,
2 Street, Singer, & Baum, 1988).

3 Yet, the task of determining a person's level of control while travelling is not
4 straightforward. A number of factors have been used as proxies for personal control, such as
5 travel predictability (Evans & Wener, 2002). A commute is seen to be less predictable when
6 factors outside of a person's control (traffic congestion, train delays) occur (Wener, Evans,
7 Phillips, & Nadler, 2003). For public transit, transfers are also seen as a cause for less
8 predictability, and thus less control (Wener, et al., 2005). However, Wener et al. (2005) also
9 argue that shorter travel times mitigate the stressful effects of transfers. One recent study used
10 self-reported ratings of predictability to determine this variable, using questions concerning
11 consistency and predictability of arrival time (Sposato, Röderer, & Cervinka, 2012). In addition
12 to predictability, having a variety of commuting options, such as different driving routes, have
13 been posited as mitigating the stress of impeded travel (Novaco, et al., 1990).

14 Comfort, or the lack of it, is also seen as a mediator of impedance. Discomfort from
15 crowding has long been associated with commuting stress, especially the stress associated with
16 public transportation (Koslowsky, et al., 1995; Lundberg, 1976). Uncomfortable heat or noise is
17 also seen to cause stress while travelling (Novaco & Gonzales, 2009; Wyon, Wyon, & Norin,
18 1996).

19 These physical or environmental occurrences, which result in a slower moving trip, lack
20 of control, or discomfort, are objective stressors that lead to a stressful commute. The subjective
21 experience of these stressors, however, is a crucial filter between the occurrence and the stress
22 experienced (refer to Figure 1, above). Ory (2004) argues that there is a difference between
23 objective mobility (the actual distance and frequency of travel using a certain mode) and

1 subjective mobility. Both objective measures of mobility and self-reported subjective measures
2 of mobility (responses to questions like “how often do you feel like you travel”) have an effect
3 on a person’s “travel-liking” (Ory, et al., 2004).

4 Novaco et al. (1979); Novaco, et al. (1990); and Koslowsky (1997) argue that the stress
5 of commuting is similarly derived not just from objective impedance but also from the mediating
6 experience of subjective impedance. How one feels about one’s trip has a mediating effect on
7 one’s experience of impedance, and thus an effect on stress. Subjective ratings by the commuter
8 regarding their satisfaction with the commute, the pleasantness of the trip (Novaco, et al., 1990),
9 or feelings about bus conditions or commuting environment (Koslowsky, 1997), have all been
10 used as measures of subjective impedance. Although both authors put forth this notion of
11 subjective impedance, they mainly focus on the subjective experience of one or two modes,
12 driving or taking public transit. Furthermore, their goal is not comparative; they are not focusing
13 on the experience of driving or public transit *per se*, but are using these modes as a petri dish
14 from which to derive a broad (mode-independent) understanding of commuting stress. This
15 study, on the other hand, argues that mode is intimately related to commuting stress. A
16 comparison of stress between modes and a comparison of mode-specific stressors offer insight
17 into the causes of commuting stress.

18

19 **Mode and Stress**

20 Surprisingly little work has been done comparing stress across all major modes of
21 transportation. We argue that a broad understanding of commuting stress cannot be derived from
22 a study of just one or two modes. Rather, mode must be understood as an important component
23 of commuting stress: different modes have inherently different variables that contribute to the

1 stress of that commute. Notions of control or lack of control vary whilst driving, walking, or
2 taking transit, and discussions of comfort and crowding vary depending on which mode is under
3 scrutiny.

4 Of the studies that have been done, many focus on the stressful effects of using an
5 automobile for commuting (for instance, Novaco, et al., 1979; Novaco, et al., 1990; Rasmussen,
6 Knapp, & Garner, 2000). Some studies have compared the stress of driving to the stress of
7 commuting on a train, finding that driving is more stressful (Wener & Evans, 2011). Very little
8 work has been done on the stress of active modes of transportation. This relative dearth is
9 perhaps because recent studies have linked active modes with higher overall life satisfaction (St-
10 Louis, Manaugh, Lierop, & El-Geneidy, 2014). In one broad comparative study, Abou-Zeid
11 (2009) found that (using self-reported stress levels on a 5-point Likert scale) active commuters
12 were the least likely to report being stressed during their commute. Drivers, on the other hand,
13 were the most likely to report stress. However, discovering mode-specific stressors may further
14 our understanding of commuting stress. It is clear that commuting using a car is a radically
15 different experience compared to walking, and, thus, the stress of these commutes occurs for
16 different reasons.

17 One recent study compared stress across active, transit, and driving modes, and found
18 that active modes of transportation are less stressful when compared to public transit or driving,
19 and that public transit is the most stressful (Gatersleben & Uzzell, 2007). However, this study
20 was not devoted to stress in itself, but was interested in ‘affective appraisals’ of a person’s
21 commute, both positive and negative. They included stress as one factor for understanding the
22 pleasantness of a commute, and, thus, the attractiveness of the mode. They found that transit was
23 the most stressful and least pleasant mode. Our study compares stress across modes and delves

1 deeper into understanding the variables, both subjective and objective, that are important
2 stressors during the use of specific modes. In this way the *reasons* behind the stress experienced
3 on a mode can be discovered. This comprehension is crucial for understanding commuting stress
4 and the steps that can be taken to lessen it. Furthermore, Gatersleben and Uzell (2007) were
5 limited by a small sample size (n=389), which only consisted of university employees
6 commuting in a semi-rural environment. Our study, focused on a large and diverse sample of
7 commuters in an urban environment, is better suited to discovering findings pertinent for urban
8 policy decisions.

9

10 **METHODOLOGY**

11 **Survey**

12 The data used for this study is compiled from a large-scale commuter survey
13 administered at McGill University in Montreal, Canada. The survey targeted a sample of
14 students (one-third of the student population), and all faculty and staff. Administered online,
15 every participant was emailed an invitation with a list of prizes that were offered as an incentive.
16 The survey was online for thirty-five days between March and April of 2013. A total of 20,851
17 survey invitations were distributed, with a response rate of 31.7%. This response rate is
18 comparable to a previous study (Whalen, Paez, & Carrasco, 2013) where they had a 22%
19 response rate. After removing partial or inadmissible cases, 5,599 surveys were kept as usable
20 responses. Because of further data requirements, discussed below, a smaller set of responses is
21 used for this study. The survey asked for a description of respondents' commute on a typical cold
22 snowy day and a typical warm dry day. Respondents were asked for in-depth details about each
23 leg of their trip, specifying the mode used and the time spent using that mode. General questions

1 regarding their satisfaction, habits, and preferences for travel were also asked, and socio-
2 demographic information was gathered.

3

4 **Sample**

5 The final sample used for this study included 3,794 responses. This sample is composed
6 of 30% staff, 20% faculty, and 50% students. The sample includes respondents who commute to
7 McGill's downtown campus (93.3%) and its Macdonald campus (located in a suburban area on
8 the island of Montreal). For this study we focused our attention on 'cold-snowy day' responses.
9 The survey was administered at the end of a long winter (snowy weather regularly continues into
10 early April in Montreal). At the time the survey was conducted the temperature was below
11 freezing for the majority of the time. Therefore, the responses to questions pertaining to winter
12 conditions, especially regarding reported levels of trip satisfaction and stress, are, we feel, better
13 representative of the levels of stress associated with commuting than questions regarding
14 summer (warm-dry) conditions. We expect that levels of satisfaction or stress reported by
15 respondents for warm-dry days is biased due to the fact that the survey was conducted at the tail-
16 end of a long winter. The temperature was below freezing in Montreal between early November
17 2012 until March 2013 and the survey was conducted in March and April. Also, respondents
18 who reported using more than one mode of transportation or stopping on their way to campus are
19 excluded from the study.

20 Respondents are assigned a variable based on their mode of transportation. If a
21 respondent only walked to their destination, they are deemed a pedestrian. Similarly, if they
22 drove to McGill they are deemed a driver (in our final sample, only 11 respondents are
23 passengers in automobiles, and are excluded from the study). Those who used public transit for

1 one leg of their trip are deemed public transit users. We originally included a sample of bicycling
2 respondents (n=64), but this sample is excluded for being too small. Table 1 shows summary
3 statistics regarding each of the included travel mode groups. This breakdown by mode is desired
4 for two reasons. First, we wish to isolate the mode specific factors that contribute to commuting
5 stress; this categorization allows us to investigate what factors affect pedestrians and compare
6 these factors to those for drivers, for example. Second, this also allows us to compare the
7 explanatory power of a general stress model (where all respondents are included) to mode
8 specific models (where one model is generated for each mode).

TABLE 1 Summary Statistics

	N	General Model		Walking		Driving		Transit	
		3783		1083		626		2074	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stress		2.92	1.28	2.67	1.31	3.19	1.23	2.96	1.26
Control Variables									
Age		35.9	13.9	29.39	11.39	44.34	13.36	36.74	13.64
Male (%)		0.39	0.49	0.39	0.49	0.42	0.49	0.37	0.48
With a Driver's License (%)		0.84	0.37	0.78	0.42	-	-	0.83	0.37
Life Satisfaction (1-10)		7.36	1.7	7.38	1.66	7.62	1.59	7.28	1.74
Income (1-10)		1.93	2.33	1.12	1.92	3.68	2.9	1.83	2.05
Days per month spent on campus		0.75	0.43	0.7	0.46	0.7	0.46	0.79	0.4
"Importance of Being Close to McGill" (1-5)		3.58	1.39	4.46	0.97	3.15	1.43	3.25	1.36
Objective Stressors									
How many modes tried in the past year		1.34	0.66	1.4	0.71	1.5	0.82	1.26	0.55
Mean Commute Time (minutes)		32.91	20.96	17.5	11.58	32.54	20.08	41.05	20.48
Mean Additional Time Budgeted (minutes)		14.76	14.46	7.32	7.29	21.15	17.44	16.65	14.69
Subjective Stressors									
"The only good thing about traveling is arriving at my destination" (1-5)		2.85	1.2	2.54	1.16	3.15	1.2	2.92	1.18
"Would Like to Walk More" (1-5)		3.24	1.21	2.94	1.16	3.72	1.17	3.25	1.19
"Would Like to use Transit More" (1-5)		2.13	1.1	1.94	1.03	2.67	1.34	2.07	1
"Would Like to Drive More" (1-5)		1.91	1.15	1.79	1.13	2.15	0.98	1.89	1.2
Mode									
Percentage Walking		0.29	0.45						
Percentage Transit		0.54	0.5						
Percentage Driving		0.17	0.37						

1 The summary statistics shown above only include variables that are applicable across all
2 groups (except percentage with a driver's license for drivers, which is redundant). Transit users
3 are the most prominent group in our sample, with over a fifty percent share. Pedestrians have a
4 higher desire to live close to McGill than the other groups (with a mean of 4.46 out of five),
5 especially when compared to drivers. A quick comparison of the mean levels of stress across the
6 different mode groups show that drivers report the highest mean stress, with transit users
7 following closely behind. Drivers also tend to be older (mean of 44 years) have the highest life
8 satisfaction of all mode groups, and tend to have a higher income than the rest of the sample, all
9 factors that are related to less stress in our models. Interestingly, they also have the highest mean
10 additional time budgeted, indicating that circumstances beyond a drivers' control necessitate
11 additional time. They also seem to have lower satisfaction with their commute, indicating that
12 subjective stressors are important components for this mode. They also tend to agree, more than
13 the other groups, that arriving at their destination is the only important component of their trip,
14 and they would like to use other modes more.

15

16 **Modeling Technique**

17 This study uses a series of ordered logit regressions to examine the relationship between
18 subjective and objective factors, modal influence, and stress. For all models, reported stress is the
19 dependent variable. The survey asked respondents if they agreed or disagreed (on a 5-point
20 Likert scale) that they "felt stressed during their commute to McGill." Since this response is
21 inherently ordinal, an ordered logit modeling technique is appropriate. For independent variables,
22 we use pertinent variables based on previous studies concerning stress and subjective well-being.
23 Control variables are included to accommodate for demographic differences and residential

1 location choices. Other variables are included to capture both objective stressors and subjective
2 experiences related to these stressors.

3 Basic personal data including age, gender, and income (divided into four levels) are
4 included. Gender has been consistently included in studies of stress and stressful commuting.
5 The common consensus is that, *ceteris paribus*, women are more likely to be stressed than men
6 (Novaco & Collier, 1994). Age squared is tested to see if there is a change in effect among
7 different age groups. Also, the respondent's main campus (downtown or at Macdonald) is tested
8 to control for any effect. Similarly, the respondent's status (student, faculty, or staff) is
9 considered. To control for the effect of residential choice (self-selection), various residential-
10 location choice variables are tested: Importance of living close to transit, importance of living in
11 a location where driving is not necessary, and importance of living close to campus (all rated on
12 a 5-point Likert scale) are evaluated. Car ownership, is another variable which should be
13 controlled for. This can be done through a variable indicating how many vehicles each household
14 has. Also, a variable indicating how many days per month spent on campus (e.g., on campus
15 twenty days a month or approximately five days a week) is used to see if the repetition of the
16 commute has any effect, both positive and negative. Finally, overall life satisfaction is also
17 included.

18 Two major objective impedance variables are included, the time of the commute, and, for
19 transit users, if they transferred or not during their commute. Beyond these objective measures, a
20 number of mediating stressor variables, approximating the level of control the person has and the
21 level of discomfort the person is experiencing, are included. The survey asked respondents to
22 report how much additional time they budgeted (in minutes) for their daily commute. This
23 variable can be used to approximate how unpredictable a commute is, and, thus, how much

1 control a person has during her trip. Another variable is included to approximate how much
2 choice a commuter has: The survey asked respondents to count how many modes (different
3 from their primary mode) they used in the last year to commute to school or work. A mode used
4 at least once in the last year indicates that this mode is at least a potential or viable option for the
5 user; those with more options available have potentially more choice and control over their
6 commute.

7 Stressors dealing with the level of comfort experienced during the commute are mode-
8 specific and hard to gather objectively. Self-rated feelings of comfort, ‘safety from crime,’ and
9 ‘safety from traffic’ are included to gain insight into these stressors. Connected to feelings of
10 comfort is the fact that a commute that is long or has an additional time budget that is excessive
11 does not directly correspond to a stressful commute. As has been discussed, the subjective
12 experience of these objective stressors is also important. To capture these subjective stressors’
13 effects, a series of variables dealing with self-reported feelings towards travel mode and
14 satisfaction with specific components of that mode are included. Respondents are asked to rate
15 their satisfaction with their commute time, cost of their commute, and other specific satisfaction
16 variables (to be discussed below). Respondents are also asked to rate whether or not they felt that
17 travel had a purpose besides arriving, and if they would like to use each mode more than they
18 currently do. These variables indicate if they have any enjoyment for their trip (beyond arriving)
19 and approximate their satisfaction with their commute and mode of the moment. These variables
20 attempt to capture similar sentiments as the ‘Travel Liking’ variable used by Ory et al. (2004).

21 In order to come to a better understanding of the effect mode has on commuter stress, and
22 to discover in greater detail the stressors of specific modes, a series of models is developed. First,
23 a general model for the entire sample is generated and includes the universal (not mode-specific)

1 variables, described above. It also includes dummy variables indicating which mode is used
2 (walking, driving, or taking transit) to measure the effect different modes have on stress. Three
3 further models are also developed, one for each mode under study. All the variables included in
4 the original general model are also present in the mode-specific models, unless they are found to
5 be insignificant. If a variable is insignificant, it is removed, and the change in the Log-Likelihood
6 of the model as well as the change in effect of other variables is studied. If little change occurs,
7 the insignificant variable is not included in our final analysis. In addition to these general
8 variables, other, mode specific variables are included.

9 All variables originally recorded using 5-point Likert responses are recoded into dummy
10 variables, where responses (1) and (2) are categorized as a ‘Low’ response, (3) as a ‘Medium’
11 response and (4) and (5) as a ‘High’ response.

12

13 *Walking Model*

14 In the walking model, only those respondents who used walking as their primary mode of
15 commuting to campus are included. For walking specific variables, ‘safety from traffic’ and
16 satisfaction with comfort are included. Safety from crime, having a driver’s license, days spent
17 on campus, and the number of viable options available are also tested.

18

19 *Driving Model*

20 Similar to the walking model, only those respondents who used an automobile as their
21 primary commuting mode are included, and these respondents are only drivers. A very small
22 sample size of automobile passengers present in the sample (n=11) limits our ability to
23 investigate this subset of automobile users, and they are excluded. Satisfaction with time and cost

1 are included as driving specific variables. Safety from crime, satisfaction with comfort, and
2 satisfaction with consistency are included as well.

3

4 *Transit Model*

5 We determine that those who use transit are those who use a public bus, train, or subway
6 for at least on leg of their trip. Included are dummy variables for the transit type used: subway,
7 bus, or commuter train. In addition, a dummy variable indicating if the respondent walked to the
8 transit station (versus drove) and if the respondent used two different modes (necessitating a
9 transfer) versus one, are included.

10 Subjective transit variables offer a unique challenge because the pertinent questions in
11 the survey are transit-type specific. These questions (dealing with respondents satisfaction with
12 time, for instance) are asked not regarding a commuter's satisfaction with time on transit in
13 general, but satisfaction with her time on the bus, her time on the subway, or her time on the
14 train, depending on which type(s) she used. To explore this level of detail but to avoid
15 developing models for each transit type, we collapsed these three subsets of the transit sample
16 into one. Most respondents did not use every transit type, and therefore did not report
17 information on their subjective experience of unused modes. For these cases, their answers to
18 these un-asked questions are coded as a 0. This code is categorized under the 'Low' level of
19 dummy variables for ranked responses. In the transit model the lowest level is excluded from
20 testing. In this manner, we have three layers of transit subjective experience, one for train, one
21 for bus, and another for subway riders. The dummy levels that remained (Medium and High)
22 explain the effect of *having* such an opinion for those who used that mode. These ranked
23 variables are similar to the ones included in the pedestrian and driving models. 'Satisfaction with

1 the consistency' of the transit type, a rating of how comfortable the type is, how satisfied the
2 rider is with the time it takes to reach the station, and the waiting time at the station are all
3 included. Satisfaction with time and safety from crime are also tested.

4

5 **RESULTS**

6 Table 2 shows the results of our regression analyses. Prior to discussing the model
7 results, we provide a comparison of the general model and the mode specific models. The reader
8 should note that the general model would usually tend toward a parsimonious structure, while the
9 mode-specific models would provide additional flexibility with higher number of model
10 parameters. Hence, any comparisons of these model structures need to weigh the advantage of
11 the mode specific models while penalizing for additional parameters. We employ the Likelihood
12 Ratio (LR) test to compare the models. The LR test statistic is defined as $2 * (LL_U - LL_R)$ where
13 LL_U and LL_R represent log-likelihood (LL) values at convergence of the unrestricted and
14 restricted models respectively. In our case, the sum of log-likelihood values of all mode-specific
15 models corresponds to the unrestricted model LL, while the general model LL corresponds to the
16 restricted model LL. The LR test statistic thus computed is compared with the chi-square
17 distribution value of k degrees of freedom where k corresponds to the additional parameters in
18 the unrestricted model, i.e. $k = \text{sum of the number of parameters in all mode-specific models}$
19 $\text{minus the number of parameters in the general model}$. The LL value sum for the mode specific
20 models is -5248.99, and the general model is -5419.93. These values yield an LR test statistic of
21 341.89, which is considerably higher than the corresponding chi-square value with 26 degrees of
22 freedom at any level of significance. A comparison of the two models using more stringent
23 criterion such as Akaike Information and Bayesian Information criterion arrive at the same

1 conclusion. The statistical comparison clearly highlights that in modeling commute stress,
2 considering stress by mode offers an improved data fit.

3 Some of the variables originally tested are removed from the final models because of
4 insignificance. Variables are removed if (a) they are insignificant in the model, (b) their removal
5 does not affect the log-likelihood of the model in question, and (c) other variable coefficients are
6 unaffected. Interestingly, most of the variables regarding residential choice (“importance of
7 living close to transit” and “importance of being in a location where driving is not necessary”)
8 are found to be insignificant, and removed. However, “importance of being close to campus” is
9 significant and is discussed below. Car ownership variable “number of cars in a household” was
10 also dropped for lack of significance. It should also be noted that one’s campus (Macdonald or
11 downtown) or one’s status (faculty, staff, or student) are both found to be insignificant.

12 Most personal controlling factors have a negative effect on stress. Age is negatively
13 associated for all models except for the transit model, where it is found not to be significant.
14 Being male or having a higher life satisfaction are also related to less stress. Importance of
15 residential proximity to campus, interestingly, has a significant but positive effect on stress. As a
16 control, it is indicating that those who find it preferable to be close to campus are likely to be
17 more stressed due to their commute while those individuals that do not consider their proximity
18 to campus to be as important are less likely to be stressed. This finding is explained by Petter
19 Næss’s claim that “travel attitudes are not the most important criteria of residential preferences,
20 and several constraints can prevent people from realizing what they would otherwise prefer”
21 (Naess, 2014, p. 70). In this study, those who indicate a desire to live closer to campus may also
22 be indicating that, at present, they cannot. Thus, their commute is more stressful. Also, by
23 testing various residential choice variables (two of which were found to be insignificant) we are

1 confident that self-selection has been controlled for. Indeed, Næss (2014) finds that various
2 residential choice variables, if included, account for little variation (around 6%), in regressions
3 modeling residential proximity to downtown.

4 “Days per month spent on campus” has an influence on only those who drove. Its
5 negative association with stress may be the result of drivers becoming more accustomed to their
6 drive. A regularity with their commute allows them to develop coping strategies and become
7 more adept at the drive, thus potentially mitigating the stressful effects of their trip (Naess, 2014,
8 p. 70). Income, at all levels, has a strong negative effect on stress both in the general model, and
9 for transit users. Interestingly, the effect is not present for drivers and less present in the
10 pedestrian model.

TABLE 2 Ordered Regression Results

		General	Pedestrian	Driver	Transit	
Log-Likelihood		-5419.93	-1512.59	-855.72	-2880.681	
		Dummy Level	B	B	B	B
Controlling Variables						
	Age*10 ⁻²	-1.347***	-2.303**	-1.264	-0.573	
	Male	-0.512***	-0.408***	-0.406*	-0.487***	
	With a driver's license	-0.373***	–	na	-0.438***	
	Life satisfaction (1-10)	-0.157***	-0.214***	-0.055	-0.107***	
Income						
	(Comparison variable) \$0-\$19,999					
	\$20,000-\$79,999	-0.304***	-0.378**	-0.083	-0.335**	
	\$80,000-\$119,999	-0.43**	-0.666**	-0.034	-0.565**	
	\$120000+	-0.451**	-0.402	-0.31	-0.607**	
	Days per month spent on campus*10 ⁻²	–	–	-3.071**	–	
	Importance of being close to McGill	High	0.327***	0.643	0.316	0.292**
Objective Stressors						
	How many modes tried in the past year	-0.127**	–	–	-0.224**	
	Commute time*10 ⁻²	1.356***	1.228**	1.363**	1.031***	
	Additional time budgeted*10 ⁻²	2.69***	3.291***	2.075***	2.229***	
Subjective Stressors						
	The only good thing about traveling is arriving at my destination	Low	–	-0.393**	–	
	The only good thing about traveling is arriving at my destination	High	0.494***	0.028	0.27	0.534***
	Would Like to Walk More	Med	-0.215**	–	–	
	Would Like to Walk More	High	–	–	0.433**	
	Would Like to use Transit More	Low	-0.273***	–	–	
	Would Like to use Transit More	High	–	–	0.58**	
	Would Like to Drive More	Low	-0.285***	–	–	
	Would Like to Drive More	High	–	–	0.291*	
Mode						
	(Comparison Variable) Driver	na	na	na	na	
	Pedestrian	-0.702***	na	na	na	
	Transit	-0.628***	na	na	na	

			General	Pedestrian	Driver	Transit
Pedestrian and Driver Variables						
	Satisfied with Time	Low	na	–	1.052***	na
	Comfortable	High	na	-0.81***	–	na
	Safe from traffic	Low	na	0.42***	–	na
	Safe from traffic	Med	na	0.52***	–	na
	Satisfied with Cost	High	na	–	-0.519**	na
Transit Variables						
	Mode Used Subway		na	na	na	-0.282
	Mode Used Train		na	na	na	0.068
	Walked to Transit Station		na	na	na	-0.322*
	two modes used		na	na	na	1.188***
Train Satisfaction						
	Satisfied with the time it takes to reach the station	Med	na	na	na	-1.152*
	Satisfied with the time it takes to reach the station	High	na	na	na	-0.901*
	Satisfied with waiting time in station	High	na	na	na	-0.49*
Subway Satisfaction						
	Consistent	high	na	na	na	-0.337**
	Comfortable	Med	na	na	na	-0.457**
	Comfortable	High	na	na	na	-0.51***
	Satisfied with waiting time in station	Med	na	na	na	-0.439**
Bus Satisfaction						
	Consistent	Med	na	na	na	-0.392*
	Consistent	High	na	na	na	-0.295*
	Satisfied with waiting time in station	Med	na	na	na	-0.44**
	Satisfied with waiting time in station	High	na	na	na	-0.793***

* p<0.05, **p<0.01, ***p<0.001, – "found insignificant, and removed", na "not applicable"

1 To determine the general effect that mode has on stress, we include dummy variables
2 indicating which mode is used in the general model. Both walking and taking transit have a
3 strong negative effect on stress when compared to driving. This finding is not unanimously
4 supported in other papers. A recent study looking at 33 urban areas in Canada found transit to be
5 the most stressful mode (Haider, et al., 2013). Ory etl al. (2004) also found that transit is the
6 most stressful. Gatersleben and Uzzell (2007) find that both driving and taking public transit are
7 stressful when compared to active modes. These discrepancies with our study can be explained
8 because of differences in study area. Our study is focused on a primarily urban population, with
9 corresponding access to a relatively wide variety of public transit options (indeed, over half of
10 our sample uses transit on a daily basis). These two other studies (Gatersleben & Uzzell, 2007;
11 Haider, et al., 2013) are focused on either a wide range of urban and semi-urban areas of Canada
12 (many of which have limited public transportation access), or a semi-rural area of England, not a
13 dense urban center.

14 Our objective stressors are aimed at measuring the direct impedance of the commute and
15 the mediating effect control and comfort have on that impact. First, our measure of commuting
16 options did have a negative effect in the general model. The result indicates that individuals who
17 have used multiple mode options are likely to feel less stressed. However, in the mode specific
18 models, this variable is only significant for transit users. This indicates that for transit users,
19 having other (possibly non-transit) commuting options lessens the stress experienced. Commute
20 time is found to be positively associated with stress both in the general model and across modes.
21 Those with a lengthier commute are, on the whole, more stressed. What is interesting is that our
22 main mediating variable, additional time budgeted, has an almost twice as large impact on stress

1 than simple commute time in all models. The more time a respondent must budget to deal with
2 unpredictable situations on her commute, the more stressed the respondent will be.

3 The subjective stressors accommodate for the impact of individual perceptions and
4 attitudes on commute stress. Similar to control and comfort, these variables have a mediating
5 effect between the actual objective instigator of stress (traffic congestion, for instance) and the
6 stress actually experienced by the commuter.

7 Agreeing with the statement that ‘the only good thing about traveling is arriving’ is
8 positively associated with stress in all models except for the pedestrian model, where *not*
9 agreeing is negatively associated with stress. This result indicates that those who do not enjoy
10 their travel for reasons other than arriving (reading, listening to music, the experience of speed,
11 for example, are more stressed, a finding corroborated by Gatersleben and Uzzell (2007). Related
12 to this effect are the variables concerning a respondent’s desire to use other modes more often. In
13 the general model, not wanting to use transit or drive more is negatively associated with stress.
14 This may indicate that if a commuter is satisfied with their mode (and therefore does not wish to
15 use another mode more often) they are less stressed. Also, in the transit model, wanting to use
16 transit or drive more is positively associated with stress. This indicates that, for transit
17 commuters, not being content with one’s commuting habits (and thus wanting to use transit or
18 drive more) leads to more stress. Similarly, for drivers, wanting to walk more than one currently
19 does means they are more likely to be more stressed during their commute. Perhaps a component
20 of the stress certain drivers feel is related to feelings of control; they feel more stressed because
21 they wish to walk to work or school, but cannot.

22

23

1 **Mode Specific Variables**

2 Comfort is a mode-specific measure: comfort while walking has nothing to do with seat
3 availability, for instance. Also, comfort is inherently a subjective occurrence. One cannot directly
4 measure the comfort a person is experiencing. Having a (self-reported) high comfort rating has a
5 negative effect on stress and is significant in the pedestrian and transit models.

6

7 *Pedestrian and Driver Subjective Stressors*

8 For pedestrians, satisfaction with time is not significantly associated with stress.
9 However, not feeling safe from traffic is positively related, which indicates that perhaps the most
10 stressful possibility of the pedestrian experience is dealing with automobiles. Our finding that
11 time is insignificant for pedestrians corroborates previous studies that find that a pedestrian's
12 satisfaction with their commute is related to the motivations (environment, finances, or
13 convenience) behind their mode choice, and has less to do with the time spent walking
14 (Mokhtarian & Salomon, 2001).

15 Conversely, for drivers, time satisfaction is important. Having a low satisfaction with
16 time is strongly and positively associated with stress. Considering they have the highest mean
17 time budget (see Table 1), time and predictability are important, and more stressful, variables for
18 drivers when compared to other modes.

19

20 *Transit Specific Stressors*

21 For transit users, no one specific transit type (subway, train, or bus) is associated with a
22 stressful commute. However, walking to your transit station, compared to driving, is negatively
23 associated with stress, and having used two modes (versus one) is strongly positively associated

1 with stress. This indicates that the unpredictability of transit commuting (which occurs when a
2 transfer between modes or driving is necessary) is a clear objective stressor. This claim is
3 substantiated by the findings related to subjective stressors.

4 For commuter-train users, being satisfied with both the time it takes to reach the station
5 and the time waiting at the station are negatively associated with stress. The unpredictability of
6 the trip to the train station, and the tense time waiting for the train once there, may help explain
7 these variables' importance. This is interesting, because for the two other transit mode types
8 (subway and bus) satisfaction with the time to reach the station is not a concern. This may
9 indicate that bus and subway stations are much more conveniently located; the trip to the station
10 does not present a potentially stressful situation.

11 However, unlike train users, feeling that one's metro or bus trip is consistent is negatively
12 associated with stress. Here, it indicates that for train users, once they are on the train the
13 consistency of the trip is not an issue, but it is an issue for metro and bus users. For subway
14 riders, comfort is also a concern. Having a high satisfaction with comfort is negatively associated
15 with stress. Finally, like train users, for subway and bus users waiting times are significantly
16 associated with stress. This indicates where perhaps the most stressful occurrence of any transit
17 trip can occur, when waiting for the service, wondering when it is going to come.

18

19 **CONCLUSION**

20 The results of this study support previous research findings regarding commuting and
21 stress (Manaugh & El-Geneidy, 2013). More importantly, this study demonstrates that the stress
22 of commuting is intimately related to the mode being used: A general conception of commuting
23 stress is not as powerful as mode-specific models. Similar to other studies, this study finds

1 driving to be the most stressful commute. However, unlike previous studies, it finds that transit is
2 not as stressful as driving.

3 Furthermore, our study confirms that commuting stress is caused by an interaction
4 between objective stressors and mediators (time, control, and comfort) and subjective stressors
5 which act as mediators (feelings, desires, and satisfaction). Driving is the most stressful mode
6 because drivers must budget a considerable amount of extra time to deal with unexpected delays
7 (their additional time budget has a mean of 21 minutes), and are more likely to be stressed when
8 they are less satisfied with the time of their commute. This additional time budget indicates that
9 they have, perhaps paradoxically, less control over their commute than commuters on other
10 modes. Frequent and unpredictable occurrences require of them a peremptory stance towards
11 their commute, where extra time becomes the best way to assure arriving to work or school on
12 time.

13 This study also indicates that public transit users, although they are not as stressed as
14 drivers, have a variety of stressors to contend with. The mode used to get to the station,
15 satisfaction with the time to reach the station (for train riders), and waiting time at the station are
16 all related to stress. All these factors can be seen as areas where control is wrested from the
17 transit user. Unpredictability can occur at any moment in the transit experience, dissatisfaction
18 with these moments may indicate a decrease in feelings of control over their situation, and thus
19 more stress. Interestingly, only in the transit model is having used other modes related to less
20 stress. It seems that having ‘a plan B’ for their commute lessens the stress of their trip. Transit
21 agencies should consider policies that could better inform users (such as accurate bus or train
22 arrival information) to lessen the stress experienced while traveling. Also, providing viable
23 alternatives could further lessen transit stress.

1 Pedestrians are our least stressed mode group. For them, satisfaction with comfort and
2 safety seem to have an important mediating effect on stress. These findings have notable policy
3 implications. Active transportation modes are not only environmentally and socially more
4 sustainable, they are also a less stressful way to travel. One way to increase pedestrian mode-share
5 is to protect walkers from traffic and provide more pleasant and more comfortable streets to walk
6 on. Furthermore, public transportation is also less stressful than driving, which is found to
7 involve (somewhat perversely) less control for commuters. Increasing the predictability and
8 range of transit options in an era of increasing driving unpredictability could lead to a greater
9 transit mode share. Further investigation into the choices commuters have as a way to compare
10 transportation modes should be studied in greater detail. For public transit users, measures of
11 viable route options, including options not using the public transit network, can be gathered. This
12 information could be easily provided to commuters, which would lessen the stress they
13 experience and potentially increase their transit use. Having these choices, it is shown, has a
14 negative effect on stress for transit users.

15 As a final note, a number of variables not included in this study impose limitations on our
16 findings, and also offer avenues for future research. Our research uses one Likert scale response
17 to measure stress. However, using a more standard stress scale while also incorporating
18 outcomes of stress (missed days at work or school, mental or physical side effects) could make
19 our findings more robust, and could be incorporated into future research. Also, a more direct
20 question relating to a respondent's subjective experience of predictability might be useful. This
21 variable could be used in conjunction with a respondent's additional time budget to measure both
22 subjective and objective effects of predictability. In this study we collected data during a cold
23 weather condition, so questions regarding good weather were excluded, as we felt some bias

1 especially towards active modes. Future research collecting data to measure stress due to a
2 commute need to be conducted across a longer time frame allowing for weather variation. Such
3 expansion in the data collected period will make the reported levels of stress more accurate and
4 representative of the impacts of different weather condition. Finally, subjective questions
5 regarding a respondent's feelings of control or a personal estimate of how much effort (physical
6 and mental) expended can greatly expand this study's findings.

7

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